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Thermophysical Properties of Mixtures of Natural Gas Components: A Bibliography of Experimental Data

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National Institute of Standards and Technology
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THERMOPHYSICAL PROPERTIES OF MIXTURES OF NATURAL GAS COMPONENTS: A BIBLIOGRAPHY OF EXPERIMENTAL DATA

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We have prepared a bibliography of references to experimental data for thermophysical properties of mixtures of natural gas components. The bibliography is based on a search of Chemical Abstracts citations from January 1980 to May 1998. The search includes mixtures containing methane, ethane, propane, isobutane, n-butane, isopentane, n-pentane, hydrogen, nitrogen, carbon monoxide, carbon dioxide, or water. The physical properties searched were phase equilibria, volumetric, and calorimetric properties, viscosity, and thermal conductivity. The properties are organized in five sections, each with a self-contained list of references.

Key words: bibliography; calorimetric; hydrocarbon; methane; mixture; natural gas; phase equilibria; thermal conductivity; viscosity; volumetric

1. Introduction

1.1 Objective

The purpose of this bibliography is to provide design engineers, data analysts, and experimentalists with a complete reference compilation to currently available data for experimental thermophysical properties of mixtures of natural gas components.

1.2 Scope

This bibliography includes references to experimental data for phase equilibria, volumetric, and calorimetric properties, viscosity, and thermal conductivity. Only articles containing original experimental data are referenced in each category. Articles containing only derived property values are excluded. The mixtures considered contain methane, ethane, propane, isobutane, normal butane, isopentane, normal pentane, hydrogen, nitrogen, carbon monoxide, carbon dioxide, or water. Mixtures containing each hydrocarbon with at least one other hydrocarbon were searched first. Mixtures containing each hydrocarbon with at least one nonhydrocarbon were searched second. Every attempt was made to ensure that all references published between January 1980 and May 1998 have been included.

The present work supplements and updates two extensive bibliographies [1,2] prepared previously in the NBS/NIST laboratories. Combined, the previous editions included references published between 1870 and January 1980. They covered an extensive list of gas mixtures, including natural gases and light gases such as helium-3, helium-4, deuterium, hydrogen deuteride, oxygen, fluorine, argon, krypton, xenon, and hydrogen sulfide. A list of eight categories of experimental data were included in the earlier editions, including vapor-liquid, solid-vapor, solid-liquid, gas-gas, gas hydrate, and liquid-liquid equilibria. This edition drops all phase equilibria except vapor-liquid equilibria and adds the categories of viscosity and thermal conductivity.

In addition to Chemical Abstracts citations, other references were taken from the Ph.D. dissertation of E. W. Lemmon [3]. This work describes a mixture model based on the Helmholtz energy for natural gas mixtures and gives comparisons to the experimental data. Additional volumetric data for the binary constituents of natural gas systems can be found in a Groupe Européen de Rechérches Gazieres (The European Gas Research Group or GERG) monograph [4] which contains several thousand data points.

1.3 Organization

The bibliography is arranged in five sections by thermophysical property. Each section is independent and contains a list of references alphabetized by author. Information on the temperature range, the pressure range, and the composition range are given where appropriate.

1.4 References

[1] Hiza, M. J.; Kidnay, A. J.; Miller, R. C. Equilibrium Properties of Fluid Mixtures: A Bibliography of Data on Fluids of Cryogenic Interest. New York: Plenum Press; 1975.

[2] Hiza, M. J.; Kidnay, A. J.; Miller, R. C. Equilibrium Properties of Fluid Mixtures-2: A Bibliography of Experimental Data on Selected Fluids. New York: Plenum Press; 1982.

[3] Lemmon, E. W. A Generalized Model for the Prediction of the Thermodynamic Properties of Mixtures Including Vapor-Liquid Equilibrium. Ph.D. Dissertation. University of Idaho; 1996.

[4] Jaeschke, M; Humphreys, A. E. The GERG Databank of High Accuracy Compressibility Factor Measurements. GERG Technical Monograph 4; 1990.

2. Experimental Properties
2.1 PHASE EQUILIBRIA

PHASE EQUILIBRIA
BINARY SYSTEMS

Table 1. Description of phase equilibria data by system.

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Nitrogen-Methane	32	140 to 160	0.65 to 4.9	Kremer (1982)
Nitrogen-Methane	10	123	0.42 to 2.6	Jin, Liu, and Sheng (1993)
Nitrogen-Ethane	32	120 to 133	0.64 to 3.6	Kremer (1982)
Nitrogen-Ethane	73	117 to 132	Up to 4.1	Llave, Luks, and Kohn (1985)
Nitrogen-Ethane	26	220 to 270	0.49 to 12	Brown, Sloan, and Kidnay (1989)
Nitrogen-Propane	17	120 to 127	0.69 to 6.2	Kremer (1982)
Nitrogen-Propane	127	188 to 343	0.08 to 5.8	Hudziak, Kahvand, Yassele, and Leipziger (1984)
Nitrogen-Propane	37	117 to 132	Up to 4.1	Llave, Luks and Kohn (1985)
Nitrogen-n-Butane	31	339 to 380	1.2 to 22	Kohn and Luks (1981)
Nitrogen-n-Butane	50	240 to 310	0.16 to 6.9	Hudziak, Kahvand, Yassele, and Leipziger (1984)
Nitrogen-n-Butane	52	250 to 344	0.04 to 16	Brown, Niesen, Sloan, and Kidnay (1989)
Nitrogen-n-Butane	31	339 to 380	1.2 to 22	Malewski and Sandler (1989)
Nitrogen-n-Butane	23	311 to 411	0.36 to 29	Shibata and Sandler (1989)

Table 1. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Carbon Dioxide-Methane	32	219 to 270	0.58 to 8.5	Al-Sahhaf, Kidnay, and Sloan (1983)
Carbon Dioxide-Ethane	136	207 to 270	0.29 to 3.6	Brown, Kidnay, and Sloan. (1988)
Carbon Dioxide-Ethane	13	260	1.7 to 2.8	Clark and Stead (1988)
Carbon Dioxide-Ethane	32	284 to 297	4.7 to 6.3	Goodwin and Moldover (1997)
Carbon Dioxide-Propane	289	211 to 350	0.06 to 5.9	Acosta, Hevla, and Leipzinger (1984)
Carbon Dioxide-Propane	90	311 to 361	Up to 6.7	Niesen and Rainwater (1990)
Carbon Dioxide-Isobutane	69	310 to 394	Up to 7.4	Weber (1984)
Carbon Dioxide-n-Butane	57	310 to 394	Up to 7.8	Weber (1984)
Carbon Dioxide-n-Butane	109	311 to 396	Up to 8.1	Niesen (1989)
Carbon Dioxide-n-Butane	140	278 to 419	Up to 8.2	Pozo de Fernandez, Zollweg, and Streett (1989)
Carbon Dioxide-n-Pentane	88	252 to 458	Up to 10	Cheng, Pozo de Fernandez, Zollweg, and Streett (1989)
Methane-n-Pentane	56	311 to 411	Up to 16	Reiff, Peters-Gerth, and Lucas (1987)

Table 1. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Ethane-Propane	151	195 to 276	Up to 2	Blanc and Settler (1988)
Ethane-n-Butane	43	303 to 363	Up to 5	Lhotak and Wichterle (1981)
Propane-n-Butane	29	303 to 363	Up to 3	Beranek and Wichterle (1981)

Table 1. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Nitrogen-Methane-Ethane	42	116 to 160	Up to 6.1	Llave, Luks, and Kohn (1987)
Nitrogen-Methane-Propane	102	116 to 160	Up to 6.1	Llave, Luks, and Kohn (1987)
Nitrogen-Methane-Propane	54	200	Up to 12.0	Trappehl and Knapp (1988)
Nitrogen-Methane-n-Butane	107	117 to 175	Up to 6.3	Merrill, Luks, and Kohn (1984b)
Nitrogen-Methane-n-Pentane	89	164 to 194	Up to 5.1	Merrill, Luks, and Kohn (1984a)
Nitrogen-Methane-n-Hexane	137	164 to 194	Up to 5.1	Merrill, Luks, and Kohn (1984a)
Nitrogen-Methane-n-Heptane	117	169 to 192	Up to 5.1	Chen, Llave, Luks, and Kohn (1989)
Nitrogen-Ethane-n-Butane	73	169 to 192	Up to 5.1	Chen, Llave, Luks, and Kohn (1989)
Carbon Monoxide-Methane-Nitrogen	23	120 to 140	Up to 4.0	Kremer and Knapp (1983)
Carbon Dioxide-Methane-Hydrogen	37	223 to 250	Up to 27.6	Freitag and Robinson (1986)
Carbon Dioxide-Methane-n-Butane	30	274 to 333	Up to 36	Pan, Yang and Guo (1995)
Carbon Dioxide-Methane-n-Hexane	113	190 to 200	4.2 to 5.6	Merrill, Luks, and Kohn (1983)

Table 1. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Carbon Dioxide-Methane-n-Hexadecane	69	293 to 423	Up to 50	Daridon, Saint-Guirons, Lagourette, and Xans (1993)
Carbon Dioxide-n-Butane-n-Decane	49	344	Up to 12	Nagarajan, Gasem, and Robinson (1990)
Methane-Ethane-Propane	36	144 to 245	Up to 7.2	Parikh, Bukacek, Graham, and Leipziger (1984)
Methane-Ethane-Propane	17	200	Up to 4.0	Trappehl and Knapp (1988)

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2.2 VOLUMETRIC PROPERTIES

VOLUMETRIC PROPERTIES
BINARY SYSTEMS

Table 2. Description of volumetric properties data by system.

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Carbon Dioxide-Nitrogen	256	323 to 348	49 to 274	0.25 to 0.74 CO_2	Hacura, Yoon, and Baglin (1988)
Carbon Dioxide-Nitrogen	196	300 to 320	0.21 to 10.6	0.11 to 0.91 CO_2	Brugge, Hwang, Rogers, Holste, Hall, Lemming, Esper, Marsh, and Gammon (1989)
Carbon Dioxide-Nitrogen	79	250 to 330	2.3 to 33.1	0.98 CO_2	Ely, Haynes, and Bain (1989)
Carbon Dioxide-Nitrogen	152	209 to 320	0.09 to 48.4	0.45 CO_2	Esper, Bailey, Holste, and Hall (1989)
Carbon Dioxide-Nitrogen	41	293	0.60 to 5.18	0.27 to 0.70 CO_2	Jiang, Wang and Shi (1990)
Nitrogen-Methane	478	82 to 320	0.59 to 35.6	0.29 to 0.68 N_2	Straty and Diller (1980)
Nitrogen-Methane	85	150 to 320	1.0 to 16.4	0.29 to 0.68 N_2	Haynes and McCarty (1983)
Nitrogen-Methane	330	323	1.0 to 34	0.10 to 0.86 N_2	Achtermann, Bose, Rogener, and St-Arnaud (1986)

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Nitrogen-Methane	39	280 to 300	0.22 to 10.5	0.50	Brugge, Hwang, Marsh, Holste, Hall, and Savidge (1989)
Nitrogen-Methane	968	270 to 353	0.32 to 28.6	0.20 to 0.75 N_2	Jaeschke and Hinze (1991)
Nitrogen-Methane	43	673	Up to 100	0.10 to 0.90 N_2	Seitz and Blencoe (1996)
Nitrogen-Methane	190	323 to 573	Up to 100	0.10 to 0.90 N_2	Seitz, Blenco, and Bodnar (1996)
Nitrogen-Ethane	488	270 to 350	0.20 to 28.7	0.25 to 0.75 N_2	Achtermann, Bose, Rogener, and St-Arnaud (1991)
Carbon Monoxide-Methane	111	116 to 125	Up to 128	0.29 to 0.79 CO	Calado, Guedes, DaPonte, and Streett (1984)
Carbon Dioxide-Methane	91	225 to 400	2.1 to 36	0.98 CO_2	Magee and Ely (1988)
Carbon Dioxide-Methane	119	206 to 320	0.08 to 48.3	0.48 CO_2	Esper, Bailey, Holste, and Hall (1989)

VOLUMETRIC PROPERTIES
BINARY SYSTEMS

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Carbon Dioxide-Methane	155	300 to 320	0.08 to 0.48	0.10 to 0.90 CO_2	Brugge, Hwang, Rogers, Holste, Hall, Lemming, Esper. Marsh, and Gammon (1989)
Carbon Dioxide-Methane	108	250 to 400	1.8 to 34.9	0.90 CO_2	Magee, Howley, and Ely (1994)
Carbon Dioxide-Methane	44	673	Up to 100	0.10 to 0.90 CO_2	Seitz and Blencoe (1996)
Carbon Dioxide-Methane	194	323 to 573	Up to 100	0.10 to 0.90 CO_2	Seitz, Blencoe, and Bodnar (1996)
Carbon Dioxide-Methane	228	225 to 350	Up to 35	0.10 to 0.90 CO_2	Hwang, Iglesias-Silva, Holste, Hall, Gammon, and Marsh (1997)
Carbon Dioxide-Ethane	234	240 to 350	1.5 to 35.3	0.25 to 0.90 CO_2	Lau (1986)
Carbon Dioxide-Ethane	255	300 to 320	0.03 to 6.83	0.10 to 0.90 CO_2	Lemming (1989)

VOLUMETRIC PROPERTIES
BINARY SYSTEMS

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Carbon Dioxide-Ethane	94	245 to 400	2.8 to 34.8	0.99 CO_2	Sherman, Magee, and Ely (1989)
Carbon Dioxide-Ethane	206	300 to 320	0.10 to 6.83	0.10 to 0.90 CO_2	Brugge, Hwang, Rogers, Holste, Hall, Lemming, Esper, Marsh and Gammon, (1989)
Carbon Dioxide-Ethane	131	303 to 333	0.68 to 6.15	0.36 to 0.67 CO_2	McElroy, Dowd, and Battino. (1990)
Carbon Dioxide-Ethane	253	290 to 320	0.14 to 12.2	0.25 to 0.74 CO_2	Weber (1992)
Carbon Dioxide-Ethane	188	240 to 450	Up to 35	0.25 to 0.90 CO_2	Lau, Hwang, Holste, Hall, Gammon, and Marsh (1997)
Carbon Dioxide-Ethane	115	292	Up to 6.2	0.06 to 0.98 CO_2	Wormald and Hodgetts (1997)
Carbon Dioxide-Propane	187	311 to 361	Up to 6.7	0 to 0.77 CO_2	Niesen and Rainwater (1990)
Carbon Dioxide-n-Butane	109	311 to 395	Up to 8.1	0 to 0.94 CO_2	Niesen (1989)
Methane-Propane	426	152 to 327	1.94 to 65.4	0.95 CH_4	Arai and Kobayashi (1980)

VOLUMETRIC PROPERTIES
BINARY SYSTEMS

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Methane-Ethane	414	100 to 320	1.67 to 35.9	0.35 to 0.69 CH_4	Haynes, McCarty, Eaton, and Holste (1985)
Ethane-Propane	315	283 to 322	2.76 to 9.65	0.30 to 0.95 C_2H_6	Parrish (1984)
Ethane-Propane	423	204 to 400	0.3 to 34.6	0.11 to 0.80 C_2H_6	Holcomb, Magee, and Haynes (1995)
Propane-i-Butane	341	200 to 400	1.2 to 35.1	0.30 to 0.70 C_3H_8	Duarte-Garza and Magee (1999)
Propane-n-Butane	513	283 to 333	0.28 to 9.65	0.10 to 0.75 C_3H_8	Parrish (1986)
Propane-n-Butane	198	236 to 414	0.06 to 34.9	0.16 to 0.82 C_3H_8	Holcomb, Magee, and Haynes (1995)
n-Butane-n-Pentane	82	241 to 410	0.01 to 2.5	0.15 to 0.78 C_4H_{10}	Holcomb, Magee, and Haynes (1995)
Methane-Water	176	398 to 498	Up to 12	0.1 to 0.5 CH_4	Joffrion and Eubank (1989)
Methane-Water	102	523 to 653	Up to 64	0.15 to 0.95 CH_4	Abdulagatov, Bazaev, and Remazanova (1993)
Methane-Water	88	430 to 699	Up to 30	0.08 to 0.68 CH_4	Fenghour, Wakeham, and Watson (1996

VOLUMETRIC PROPERTIES
BINARY SYSTEMS

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Methane-Hydrogen	160	273 to 600	0.3 to 72	0.80 CH_4	Magee, Pollin, Martin, and Kobayashi (1985)
Methane-Hydrogen	170	140 to 273	1.0 to 70	0.80 CH_4	Magee and Kobayashi (1986)
Methane-Hydrogen	296	130 to 159	1.7 to 107	0.09 to 0.92 CH_4	Machado and Street (1988)

Table 2. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE
Nitrogen-Carbon Dioxide-Methane	39	245 to 400	3.5 to 33.0	Magee, Howley, and Ely (1994)
Nitrogen-Carbon Dioxide-Methane	242	323 to 573	Up to 100	Seitz (1994)
Nitrogen-Carbon Dioxide-Methane	271	323 to 573	Up to 100	Seitz, Blencoe, and Bodnar 1996)
Nitrogen-Methane-Ethane	101	275 to 345	Up to 60	Staby and Mollerup (1991)
Carbon Dioxide-Methane-n-Butane	132	274 to 310	Up to 12	Pan, Yang, and Guo (1995)
Carbon Dioxide-Methane-n-Hexadecane	389	293 to 423	Up to 50	Daridon, Saint-Guirons, Lagourette, and Xans (1993)
Carbon Dioxide-Ethene-Propane	189	294 to 311	Up to 12	Ashcroft and Shearn (1985)
Carbon Dioxide-Propane-Methanol	185	323 to 398	Up to 40	Galicia-Luna, Richon, and Renon (1994)
Carbon Dioxide-n-Butane-n-Decane	30	344	Up to 12	Nagarajan, Gasem, and Robinson (1990)

Bibligraphy – Volumetric Properties

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2.3 CALORIMETRIC PROPERTIES

CALORIMETRIC PROPERTIES
BINARY SYSTEMS

Table 3. Description of calorimetric properties data by system.

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE	REMARKS
Nitrogen-Carbon Dioxide	65	250 to 350	0.52 to 10.3	0.50 N_2	Younglove, Frederick, and McCarty (1993)	Sound Speed
Nitrogen-Methane	63	173 to 298	200 to 750	0.50 N_2	Zhang and Schouten (1992)	Sound Speed
Nitrogen-Methane	265	250 to 350	0.09 to 11	0.05 to 0.29 N_2	Younglove, Frederick, and McCarty (1993)	Sound Speed
Nitrogen-Propane	60	241 to 393	0.1	0.30 to 0.70 N_2	Wormald, Hutchings, and Lewis (1996)	Enthalpy
Nitrogen-n-Butane	40	241 to 393	0.1	0.30 to 0.70 N_2	Wormald, Hutchings, and Lewis (1996)	Enthalpy
Carbon Dioxide-Methane	60	293 to 313	Up to 4.6	0.20 to 0.80 CO_2	Barry, Kaliaguine, and Ramalho (1982)	Enthalpy
Carbon Dioxide-Methane	241	250 to 350	0.45 to 11	0.05 to 0.30 CO_2	Younglove, Frederick, and McCarty (1993)	Sound Speed
Carbon Dioxide-Ethane	199	248 to 308	Up to 11	0 to 0.95 CO_2	Wormald and Eyears (1988)	Enthalpy
Carbon Dioxide-Ethane	79	230 to 350	Up to 18	0.10 to 0.90 CO_2	Moller, Gammon, Marsh, Hall, and Holste (1993)	Enthalpy

CALORIMETRIC PROPERTIES
BINARY SYSTEMS

Table 3. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE	REMARKS
Carbon Dioxide-Ethane	260	220 to 340	Up to 35	0.25 to 0.74 CO_2	Magee (1995)	C_v
Carbon Dioxide-Ethane	115	292	Up to 6.2	0.06 to 0.98 CO_2	Wormald and Hodgetts (1997)	Enthalpy
Carbon Dioxide-n-Butane	20	231	Up to 2	0.15 to 0.85 CO_2	Guedes, Zollweg, and Streett (1991)	Enthalpy
Methane-Ethane	626	101 to 328	Up to 25	0.35 to 0.69 CH_4	Mayrath and Magee (1988)	C_v
Methane-Ethane	392	250 to 350	Up to 11	0.35 to 0.95 CH_4	Younglove, Frederick, and McCarty (1993)	Sound Speed
Methane-Propane	76	250 to 350	0.48 to 10.4	0.90 CH_4	Younglove, Frederick, and McCarty (1993)	Sound Speed
Propane-i-Butane	135	203 to 342	3.3 to 33.0	0.30 to 0.70 C_3H_8	Duarte-Garza and Magee (1988)	C_v

Table 3. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	REFERENCE	REMARKS
Carbon Dioxide-Hydrogen Sulfide-Methane	39	293 to 313	Up to 1.5	Barry, Kaliaguine, and Ramalho (1983)	Enthalpy
Carbon Dioxide-Methane-Ethlylene	36	293 to 313	Up to 3.4	Gagne, Kaliaguine, and Ramalho (1986)	Enthalpy

CALORIMETRIC PROPERTIES
AQUEOUS SYSTEMS

Table 3. (continued)

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE MOLE FRACTION	REFERENCE	REMARKS
Methane-Water	62	Up to 698	Up to 12.6	0.5 H_2O	Wormald and Colling (1984)	Enthalpy
Methane-Water	69	373 to 423	0.1	0.26 to 0.49 H_2O	Smith, Sellars, Yerlett, and Wormald (1983)	Enthalpy
Methane-Water	15	314 to 704	Up to 28	---	Hnedkovsky and Wood (1997)	*Cp*
Ethane-Water	40	363 to 393	0.1	0.32 to 0.70 C_2H_8	Lancaster and Wormald (1985)	Enthalpy
Propane-Water	40	363 to 393	0.1	0.35 to 0.70 C_3H_8	Lancaster and Wormald (1986)	Enthalpy
Propane-Water	102	468 to 698	Up to 13.7	0.50 C_3H_8	Lancaster and Wormald (1987)	Enthalpy

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2.4 VISCOSITY

VISCOSITY
BINARY SYSTEMS

Table 4. Description of viscosity data by system.

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Carbon Monoxide-Methane	5	298 to 473	0.1	0.33 to 0.68 CO	Kestin and Ro (1983)
Nitrogen-Methane	306	100 to 300	Up to 30	0.29 to 0.68 N_2	Diller (1982)
Carbon Dioxide-Ethane	64	210 to 320	Up to 30	0.25 to 0.74 CO_2	Diller, Van Poolen, and Dos Santos (1988)
Carbon Dioxide-Ethane	74	320 to 500	Up to 30	0.25 to 0.74 CO_2	Diller and Ely (1989)
Carbon Dioxide-Ethane	224	298 to 625	0.1	0.25 to 0.74 CO_2	Hendl and Vogel (1993)
Methane-Ethane	324	100 to 300	Up to 30	0.25 to 0.74 CO_2	Diller (1984)

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2.5 THERMAL CONDUCTIVITY

THERMAL CONDUCTIVITY
BINARY SYSTEMS

Table 5. Description of thermal conductivity data by system.

SYSTEM	NUMBER OF POINTS	TEMPERATURE RANGE, K	PRESSURE RANGE, MPa	COMPOSITION RANGE, MOLE FRACTION	REFERENCE
Carbon Dioxide – Nitrogen	82	321 to 473	1.0 to 30.8	0.29 to 0.84 CO_2	Johns, Rashid, Rowan, Watson, and Clifford (1988)
Carbon Monoxide-Methane	41	301	Up to 12	0.23 to 0.75 CO	Imaishi and Kestin (1984)
Nitrogen-Methane	55	301	Up to 8	0.23 to 0.64 N_2	Kestin, Nagasaka and Wakeham (1982)
Carbon Dioxide-Methane	48	301	Up to 6	0.21 to 0.73 CO_2	Kestin, Ro, and Nagasaka (1982)
Carbon Dioxide-Ethane	62	298 to 308	Up to 9	0.10 to 0.88 CO_2	Yorizane, Yoshimura, Masuoka and Yoshida (1983)
Carbon Dioxide-Ethane	15	302 to 308	Up to 9	0.25 to 0.58 CO_2	Mostert, van den Berg, Van der Gulik and Sengers (1992)
Methane-Ethane	2476	140 to 330	0.1 to 70	0.35 to 0.69 CH_4	Roder and Friend (1985)
Methane-Ethane	60	257 to 311	6.2 to 16.2	0.5 CH_4	Sakonidou, van den Berg, and ten Seldam (1998)

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